INVESTIGATION 13-C

Measuring the Mass-to-Charge Ratio for Electrons

TARGET SKILLS

- **Identifying variables**
- **Performing and recording**
- **Conducting research**

In this investigation, you will perform an experiment very similar to the one in which J.J. Thomson discovered and characterized the electron. You will accelerate electrons by means of a large potential difference and then deflect them in a cathode ray tube by means of a known magnetic field.

Problem

(1) Determine the speed of electrons that pass through a cathode ray tube and **(2)** measure the ratio of the mass to the charge for the electron.

Equipment

- DC power supply for heated cathode tubes
- Helmholtz coils
- DC power supply for Helmholtz coils
- ammeter
- Thomson deflection tube

CAUTION Avoid touching the high voltage connections.

A cathode ray tube emits a small amount of X rays, so stay in front of it very briefly.

Procedure

1. With all power supplies turned off, set the anode voltage to zero.
2. Connect the Thomson deflection tube to the power supply according to the instructions in the manual for the tube. Check that all connections are secure and correct.
3. Set the power supply for the Helmholtz coils to zero. Connect the ammeter in series with the power supply and the coils.
4. Measure the radius of the Helmholtz coils (or record the value provided with the coils).
5. Turn on the deflection tube power supply. Make sure that the filament voltage is set correctly, according the manual (probably 6.3 V).
6. Increase the anode voltage to 5000 V and observe the glowing trace of the cathode rays across the screen.
7. Gradually increase the voltage of the Helmholtz coils until the electron beam has been strongly deflected by the time the beam leaves the screen. Ensure that the maximum current for the coils is not exceeded. Record the value of the current.
8. Record the coordinates for two grid points along the trajectory of the beam.
9. Reduce all voltages to zero and turn off the power supplies.

Calculating the Radius of the Circular Trajectory

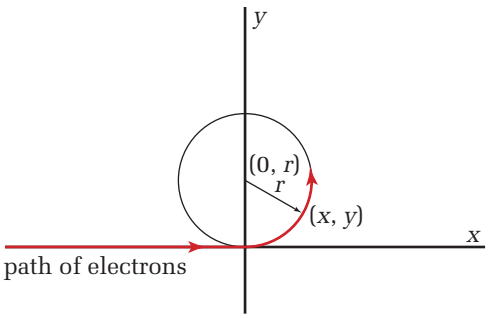
In general, the distance between any two points with known coordinates is given by

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

For the circular trajectory, the distance between any point on the circle and the centre is the radius, r.

Since the deflection begins when the beam passes throught the origin of the graph, the centre of the circle must be at $(0, r)$

Thus, $r = \sqrt{(x - 0)^2 + (y - r)^2}$ (3)



Analyze and Conclude

1. **(a)** State the coordinates for the two observed points on the electron beam's trajectory.
   (b) Write an expression for r based on the equation given above.
   (c) Calculate the value of r for each point and find the average. Use this average in your further calculations.
2. The magnetic field between the two Helmholtz coils is given by the equation

$$B = \frac{32\pi nI}{5\sqrt{5}(R_c)} \times 10^{-7}\ \text{T},$$

   where n is the number of turns in the coils (as indicated on the coils), I is the current in amperes, and R_c is the radius of the coils. Calculate the magnetic field (B) between the coils.
3. Use the equation $v = \frac{2V}{Br}$ to determine the speed of the electrons. Substitute the value for v into an expression, $\frac{m}{e} = \frac{2V}{v^2}$, to find the charge-to-mass ratio.
4. Review the information in Chapter 8, Fields and Their Applications, about the motion of charged particles moving through a magnetic field and derive the equations above.

13.3 Section Review

1. K/U How do physicists know of the existence of particles with lifetimes that are as short as 10^{-10} s, and how can they determine any properties of these particles?
2. K/U Why are the electrons in the lowest energy level of an atom not affected by the strong nuclear force?
3. K/U
   (a) State two ways in which leptons differ from hadrons.
   (b) In what ways are mesons similar to baryons?
   (c) How are mesons different from baryons?
4. MC Using quark notation, how could you represent **(a)** a negative pion and **(b)** an antiproton?
5. MC An antineutron must be neutral and have exactly the same mass as the neutron. What should its quark composition be?
6. I If neutrinos barely interact with matter, how can they be detected? Research the question and provide a diagram to explain the process.